Qualcomm

Qualcomm Incorporated

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February 18, 2022

***Ex Parte* Notice**

Marlene Dortch
Secretary
Federal Communications Commission
45 L Street NE
Washington, DC 20554

Re: In the Matter of Amendment of Section 15.255 of the Commission's Rules, ET Docket No. 21-264

Dear Ms. Dortch:

On February 16, 2022, representatives from Intel Corporation, Meta Platforms, Inc., and Qualcomm Incorporated (the "Companies") met via video conference with staff from the FCC's Office of Engineering and Technology to discuss the Commission's proposals to update the rules for radar operations in the 60 GHz band and present results of interference testing showing the impact of radar operations to communications links in that band. A list of the meeting participants and slide presentation used during the meeting is attached.

The Companies explained that the 60 GHz band is uniquely suited for the emerging AR/VR/XR applications that require high throughput and sustained ultra-low latency in the single digit milliseconds range. Sales of AR/VR/XR-enabled head-mounted displays with real-time communications capabilities is projected to increase exponentially over the next several years.[1] Because of this, our Companies want to ensure that the 60 GHz band remains a band in which both communications and radar operations can successfully co-exist without detrimentally impacting important new technologies. As detailed in the slide presentation, our Companies tested common operational scenarios that demonstrate that radar operations, operating in accordance with proposals in the NPRM, substantially impact the latency performance of 60 GHz short-range communications links that will support AR/VR/XR applications.[2]

While 60 GHz communications applications operating under the 802.11ad/ay IEEE standard use channels 2.16 GHz wide and implement a Listen-Before-Talk mechanism to

[1] 2022 Trends to Watch: The Data Behind the Tech, i3 It Is Innovation, CES, January/February 2022 (projecting sales of 4 million AR/VR/XR headsets in 2022 and more than 13 million in 2025 in the U.S. alone).

[2] Notably, the testing parameters do not reflect the worst-case interference scenario, such as where radars are operating much closer to 60 GHz receivers than what was tested where a user is wearing a 60 GHz radar-enabled watch while using an AR/VR/XR Head Mounted Display connected to a transceiver across the room near a video screen.

ensure coexistence with other devices in the band, Frequency Modulated Continuous Wave (FMCW) radars the NPRM proposes to permit in the entire 57-64 GHz band, operate without sensing the medium before transmitting. Even though multiple 802.11ad/ay communications devices can operate in an interference-free basis in close proximity to one another in adjacent channels or politely share the access time in the same channel based on priority, an FMCW radar operating in the 57-64 GHz band with a 10 % duty cycle can use very short transmission "on" and "off" times and effectively block all communications across the entire 7 gigahertz spectrum block.

To ensure these two different technologies successfully co-exist in the 60 GHz band, the Companies urge the Commission to adopt the additional condition it imposed in all five 60 GHz waiver orders it adopted in July 2021.[3] Specifically, the Commission should require radar operations to include any "off time" between two successive radar pulses less than 2 milliseconds to be considered "on time" for purposes of computing the 10% duty cycle. This simple "loophole closing condition" is necessary to ensure reasonable coexistence between radars and communications devices in this important band.

The Companies also explained that allowing higher radar power levels than what the FCC permitted in every 60 GHz waiver order will have a much greater impact on communications operations. The Companies' testing shows the impact of this greatly increased power level, in different distances and orientations, to the latency of a communications link. The 20 dBm EIRP proposed for radar operations will increase the interference zone, double the impact range, and significantly widen the impact angle. In contrast, a radar operating at 13 dBm EIRP (i.e., the maximum power level allowed under the waiver orders) can be better tolerated by communications applications so long as the Commission adopts the requirement discussed above to require any off time between two successive radar purposes less than 2 milliseconds be counted as "on time" for purposes of the 10% duty cycle calculation.[4]

The Companies will continue working with the Commission and the radar companies currently operating pursuant to FCC waiver authority to ensure the 60 GHz band remains a band that fosters innovation while allowing the important and very different technologies to successfully co-exist.

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[3] *See* FCC OET Letter Granting Petition of Faurecia Clarion Electronics North America regarding 47 CFR § 15.255, ET Docket No. 21-288, DA 21-811 (rel. July 9, 2021); see also FCC OET Letter Granting Request by Texas Instruments Incorporated for Waiver of 47 CFR § 15.255(c)(3), ET Docket No. 21-290, DA 21-813 (rel. July 9, 2021); FCC OET Letter Granting Request by Amazon.com Services LLC for Waiver of 47 CFR § 15.255(c)(3), ET Docket No. 21-289, DA 21-813 (rel. July 9, 2021); FCC OET Letter Granting Request by Vayyar Imaging Ltd. for Waiver of 47 CFR § 15.255 rules, ET Docket No. 20-15, DA 21-815 (rel. July 9, 2021); Request by Huyndai Mobis Co., Ltd. for Waiver of 47 CFR §§ 15.255(a)(2) & (c)(3), ET Docket No. 21-287, DA 21-816 (rel. July 9, 2021).

[4] Testing of a single radar burst lasting 3.3 ms showed latency impact to communications links less than 10 ms. See slide 19 of attached powerpoint presentation.

If you have any questions, please do not hesitate to contact me.

Respectfully submitted

Aspasia A. Paroutsas
Vice President, Federal Regulatory Affairs

Atts.

cc (w/ Atts.): FCC meeting participants

Participants:

Federal Communications Commission – Office of Engineering and Technology
Ron Repasi
Ira Keltz
Michael Ha
Nick Oros
Bahman Badipour
Anh Wride
Damian Ariza

Intel Corporation
Carlos Cordeiro

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Alan Norman
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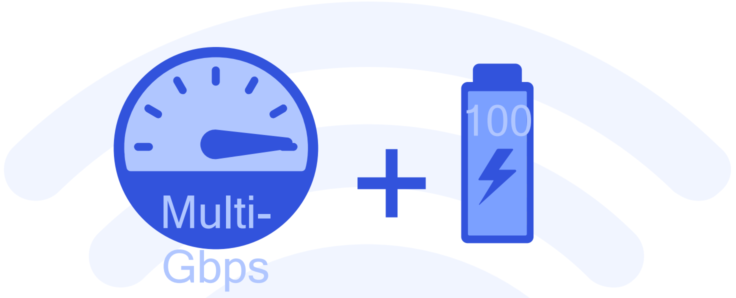
60 GHz Spectrum Considerations

February 16, 2022

Intel, Meta Platforms, Qualcomm

60 GHz Band value proposition and usages

- Value proposition of the 60 GHz band
  - Wide bandwidths enable high throughput, high capacity, low latency, and fine time resolution
  - Small wavelength enables antenna array on small footprint. Narrow beam leads to large capacity and fine spatial resolution
- Two broad usage categories:



Communication
Multi-Gigabit @ Low Latency & Low power
(e.g., 11ad/ay)

Sensing/radar
with fine time and spatial resolution
(e.g., FMCW radar, 11ad/ay radar)

- The 60 GHz band is especially important for emerging AR/VR/XR applications with stringent latency and large throughput requirements
  - One-way wireless communication link latency must be sustained in single digit milliseconds
  - VR sickness (similar to motion sickness) is linked to high Motion-to-Photon (M2P) latency – between body movements and corresponding user view update

AR/VR/XR Applications

- Revolutionary interfaces that merge real world with virtual objects, enabling physical presence in virtual worlds
- Unprecedented experiences and possibilities
  - Enterprise & Home environments
    - Healthcare
    - Industrial (operation of complex machinery)/Engineering/Architecture
    - Education/training/remote work
  - Mission-Critical Services/Public Safety/Defense/Military
  - Entertainment/Gaming
- High throughput and ultra low latency is critical for AR/VR/XR immersion
  - Ultra high-definition video: lag, stutter and stalls impacts user experience and overall service
  - Better interactivity and expanded use cases
    - Interactive remote experiences
  - Uniform user experience

Latency, not just bandwidth, is a limiting factor for interactive applications

- End-to-end application latency is critical for interactive applications
  - For AR/VR, per John Carmack, CTO Oculus VR,

    "Human sensory systems can detect very small relative delays in parts of the visual or, especially, audio fields, but when absolute delays are below approximately 20 milliseconds [for M2P/two-way] they are generally imperceptible. "

    "If large amounts of latency are present in the VR system, users may still be able to perform tasks, but it will be by the much less rewarding means of using their head as a controller, rather than accepting that their head is naturally moving around in a stable virtual world. Perceiving latency in the response to head motion is also one of the primary causes of simulator sickness."

    See https://www.wired.com/2013/02/john-carmacks-latency-mitigation-strategies/
- For AR/VR application, end-to-end application latency is M2P latency which includes both processing (rendering etc.) latency and two-way communication link latency.
- **For one-way wireless communications link 99% packet latency needs to be less than 10 ms.**

Sustained Single Digit Milliseconds Latency Critical for AR/VR/XR Applications

- IEEE and 3GPP standards provide for single digit millisecond latency requirements
  - https://mentor.ieee.org/802.11/dcn/19/11-19-0065-06-0rta-rta-tig-summary-and-recommendations.pptx
  - https://www.3gpp.org/ftp/Specs/archive/22_series/22.261/22261-i50.zip

- AR/VR/XR devices and applications will grow exponentially this decade and use increased video resolution and frame rates
  - 2022 – projected 4 million headsets
  - 2025 – projected 13.2 million headsets*

* 2022 Trends to Watch: The Data Behind the Tech, i^3 It Is Innovation, CES, January/February 2022

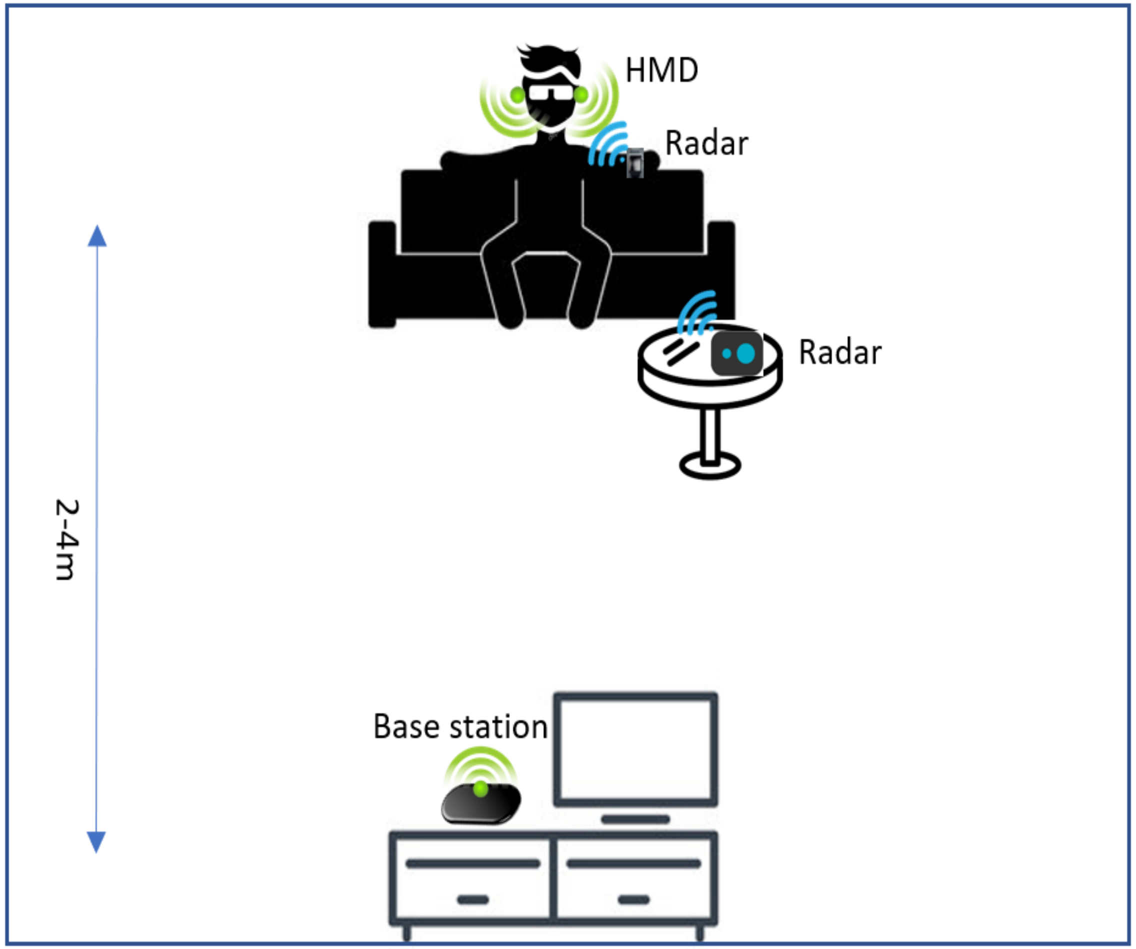
Primary Considerations in ET Docket 21-264

Update rules for 60 GHz radar operations while ***promoting compatibility*** with unlicensed communications operations that have long been permitted in the band

Forward-looking regulations that support ***fair sharing*** and ***technology evolution*** for ***all*** unlicensed applications and services that will use this important unlicensed band

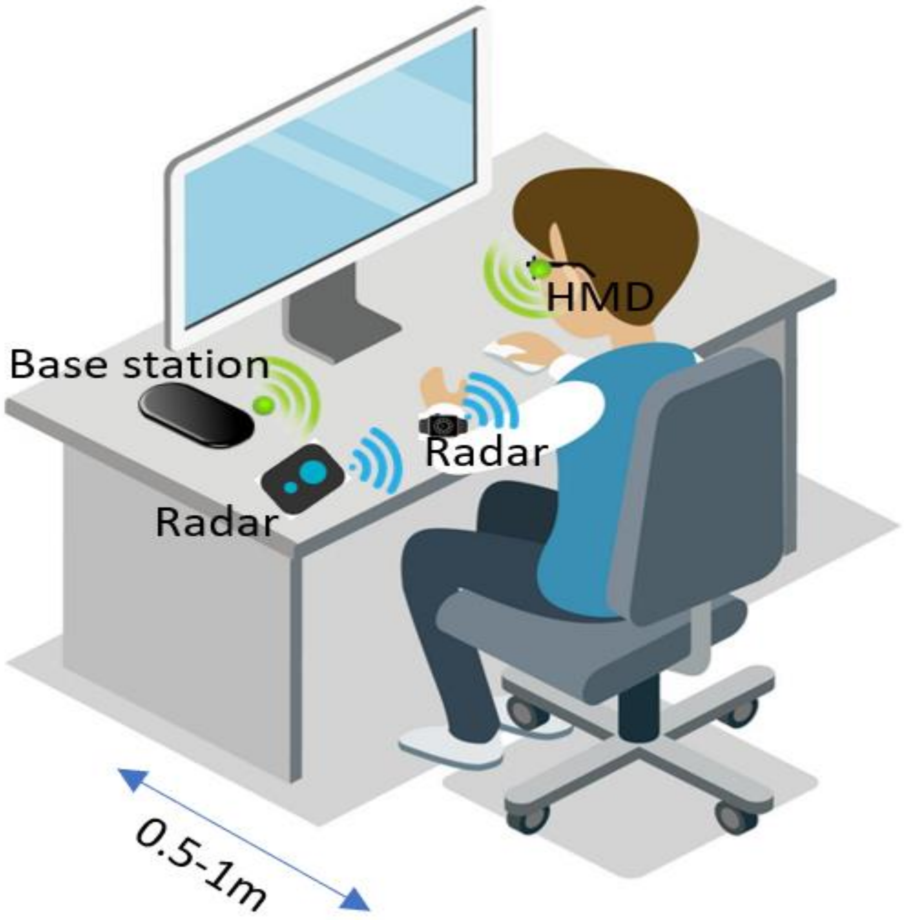
Radar Proponents Fail to Address Co-Existence Concerns Raised on the Record

Radars and Communication devices operating in Close Proximity introduce Co-Existence Issues – Living Room



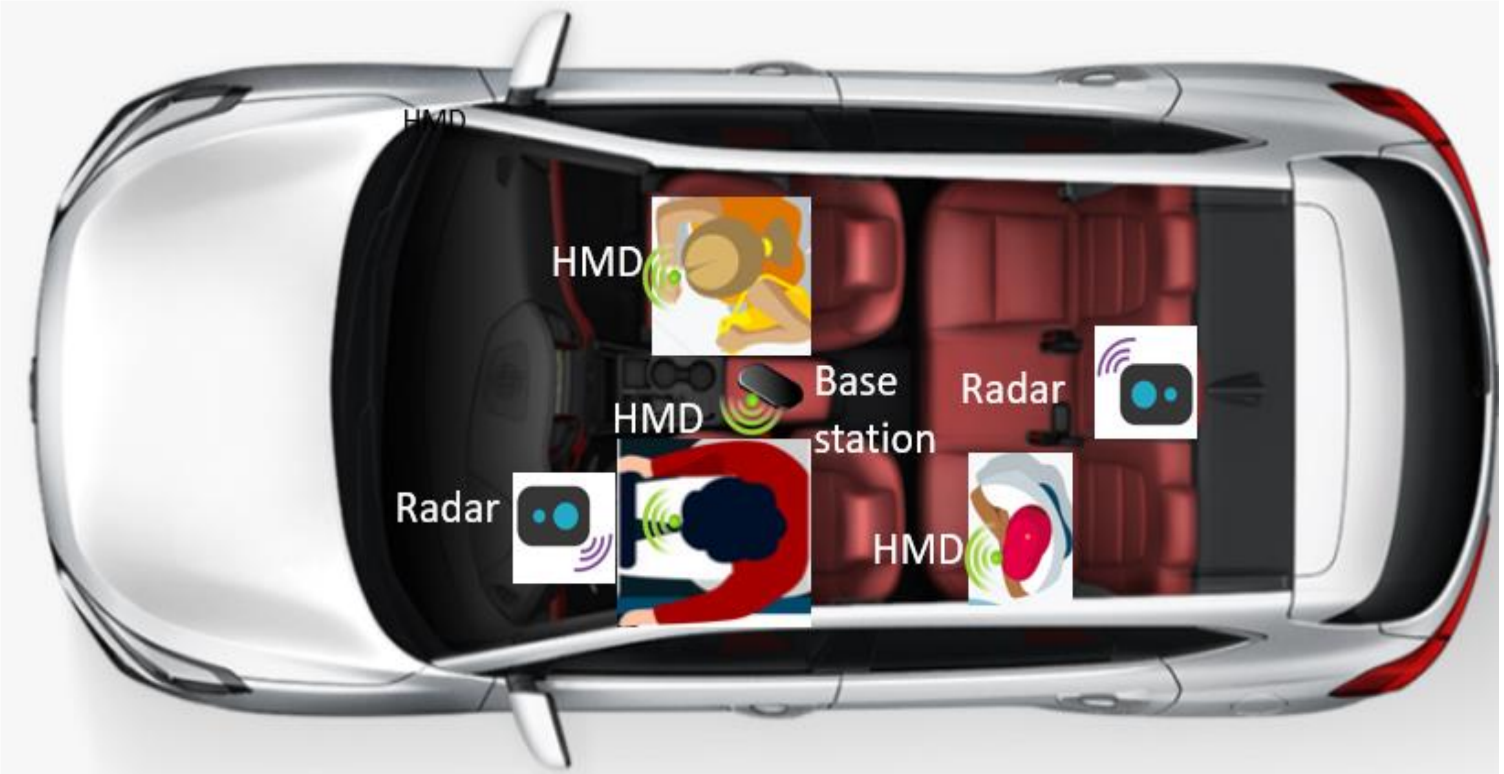
- There can be 60 GHz communications operations in close proximity to 60 GHz radars in the living room setting
- User(s) may be wearing Head-Mounted Displays ("HMD") playing a game or watching a video and there may be radars mounted on a wall, placed on a table, and user worn

Radars and Communication devices operating in Close Proximity introduce Co-Existence Issues – Office Settings



- There can be 60 GHz communications operations in close proximity to 60 GHz radars in home and business office settings
- User(s) may be using a 60 GHz wireless docking station, wearing an HMD projecting a virtual workspace, and 60 GHz radars may be on the desk, mounted on a wall, and user worn

Radars and Communication devices operating in Close Proximity introduce Co-Existence Issues – Vehicle



- There can be 60 GHz communications operations in close proximity to 60 GHz radars inside vehicles
- Drivers and passengers may be wearing a HMDs (supporting driver assist tools and passengers playing games/watching videos), and there will be radars in the dashboard and back seat monitoring driver alertness, vehicle safety applications, and baby breathing

Impact of FMCW Radar to 60 GHz Communications

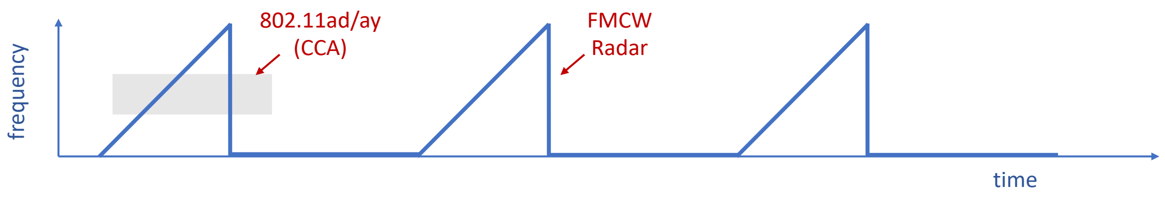
Radar may occupy the entire bandwidth and operate with very short gaps between transmission chirps that can either effectively block 60 GHz communications from accessing the channel <u>or </u>repetitively disrupt ongoing 60GHz communications transmissions.

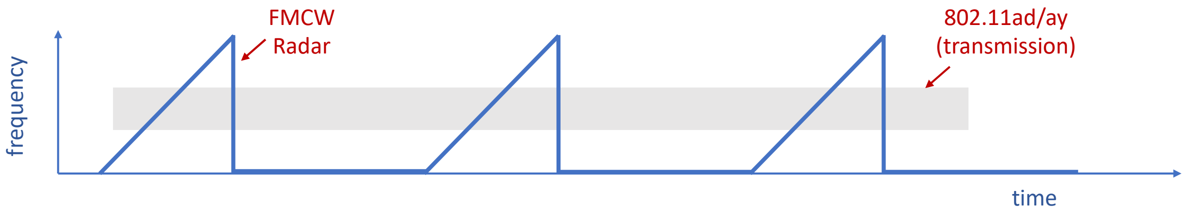
<u>Communications devices could be blocked (busy CCA) when accessing the channel</u>

- Multiple nearby communications devices/networks could avoid interference by using different channels
- However, FMCW transmissions may span the entire 60 GHz band

<u>Reception of Communications signals could be interfered by radar transmission</u>

- If FMCW radar implementations do not perform CCA, radar transmissions may occur even if channel is used by other devices





Impairing Access to the 60 GHz Band

- Problem: FMCW radar may use very short gaps between transmissions to satisfy the duty cycle requirement, e.g., it can transmit pulses for 10 µs followed by 90 µs of off time, and effectively block 60 GHz band communications
  - While such radar operations comply with the 10% duty cycle requirement, 90 µs of off time is too short for nearby communications devices to effectively utilize the channel
  - If this duty cycle loophole is not addressed, FMCW radars can occupy the entire 7 GHz-wide band and block/impair nearby communications device operations
- 60 GHz band communication sequence includes random backoff, request-to-send (RTS) and clear-to-send (CTS) frames, message transmission and Block acknowledgment (ACK), as well as the interframe spacing, as a result it cannot efficiently utilize the short gap
  - Protocol Overhead: Random backoff +RTS+CTS+ Block ACK + Interframe spacing already takes 72 to 147µs
  - Message transmission duration depends on the payload size and data rate used.
    - Even for minimum AR/VR traffic load of 100Mbps at 45Hz frame rate takes appx. 2 ms transmission time using around 1 Gbps (MCS4) phy rate.

Ensuring Communications Access to the 60 GHz Band

<u>Proposed Solution</u>: Require any radar off-time between two successive radar pulses less than 2 milliseconds be considered “on time” for purposes of computing the 10% duty cycle

- Closes the loophole in the duty cycle definition permitting continuous harmful radar operations
- Will prevent radar devices from operating continuously with such a small period of time between transmissions that preclude the ability of communications devices to use the band effectively
- Already a condition imposed on multiple waiver orders; condition not impeding desired radar operations

Increased Radar Power Increases the Potential for Interference to Communications Devices

- Radar proponents’ studies ignore radar’s impact on communications latency performance; only focus on throughput
- Studies and tests use incorrect assumptions and configurations:
  - Use incorrect power level for radars: Google study uses 7 dBm power level; not even the 13 dBm level approved under its waiver or the NPRM’s proposed 20 dBm level
  - Unrealistic link budget for communications links: Testing assumes ideal condition of communications link, i.e., high EIRP, very narrow beam and very short communication distance. Real-life AR/VR/XR applications will operate with worse link budget and wider beams, making it more susceptible to interference
- Presence of radar devices on the market is not dispositive as to coexistence with communications applications
  - Soli devices are not widely deployed
  - Latency-critical communications applications like AR/VR/XR are at early deployment stages

Ensure Coexistence between Radar and Communications Operations in the 60 GHz Band

- Do not increase EIRP for radar operations to 20 dBm
  - Proposed value is more than 4 times the value allowed under all prior 60 GHz Waiver Grant Orders
  - A 20 dBm EIRP level would greatly increase the zone of interference, especially as multiple radar devices operate in close proximity to communications devices
- Power should be measured as peak rather than average
  - Average power measurements allow radar devices to use beam switching to satisfy EIRP limit requirement and effectively operate at a much higher EIRP
- Power should be assessed exclusively during transmission (i.e., only over the chirp or pulse duration), as stated in NPRM para 29, not full duty cycle
- Do not rely on ETSI specification EN 305-550
  - ETSI never conducted co-existence studies
  - EN 305-550 values do not reflect realistic co-existence with the 60 GHz communications industry

Radar – 60 GHz Band Communications Coexistence Testing

Overview of Testing

- Performance metric: **One-Way Latency**
  - AR/VR/MR applications require single digit milliseconds latency over the wireless link at desired traffic load

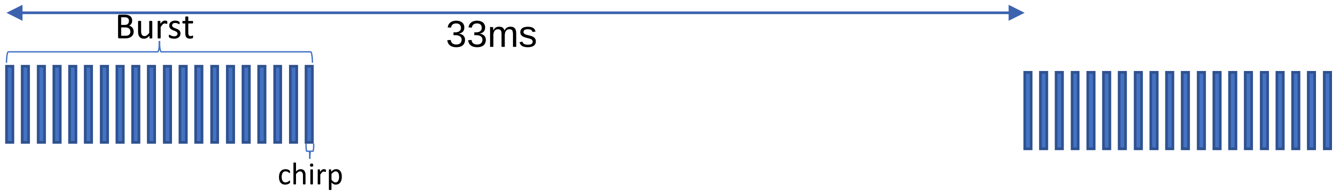
- Testing is conducted in a laboratory setting using stationary devices
  - The test measures the 99-percentile (P99) end-to-end latency over the 60 GHz communications link
  - Devices are synchronized using the Precision Time Protocol (PTP) over a separate wired network for accuracy
  - The test injects one way traffic with a specified traffic load

- Equipment Used
  - FMCW radar: ~2GHz centered at 60.48 GHz using Litepoint
  - Communications Devices: also centered at 60.48 GHz, with 2.16 GHz BW

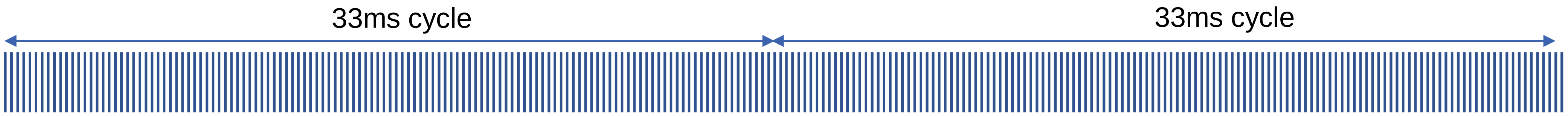
Radar Patterns Tested

- Single burst of 3.3ms
  - One burst of 3.3ms on (satisfies 10% duty cycle)
  - 29.7ms of continuous silence time

- Google Soli parameters (A4RGUIK2)
  - Chirp period: 130.8µs On+200µs Off= 330.8µs
  - Number of chirps per burst = 20, Burst duration = 6.4ms
  - 7.9% duty cycle (computed based on Tx time) and 19% duty cycle (computed based on burst time)

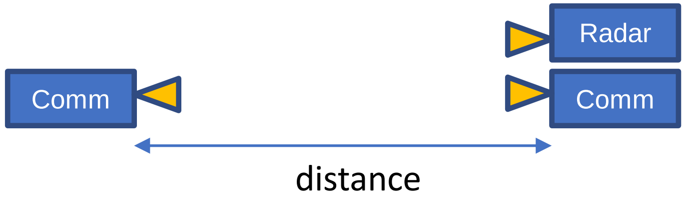


- Continuous radar allowed by Google Soli Waiver Order
  - Chirp period: 18µs On + 162µs Off = 180µs
  - Continuous chirp period in 33ms cycle. 10% duty cycle (computed based on Tx time)



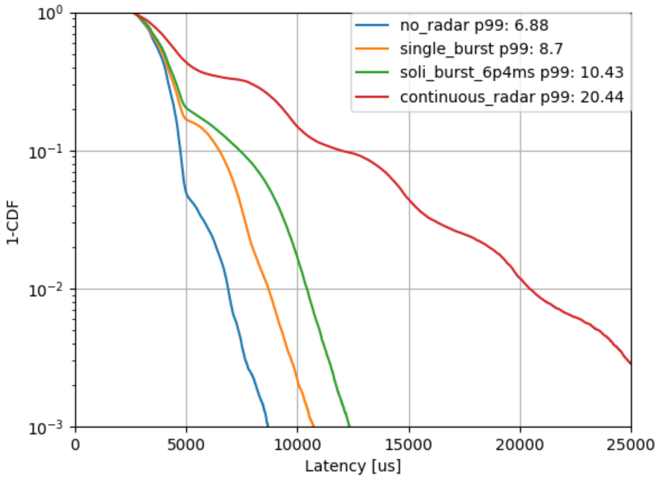
Testing Latency Impact of Different Radar Patterns

- Setup
  - Orientation: 0^o angle
  - Distance: 1.8m
  - Radar power: 13dBm



- Testing results

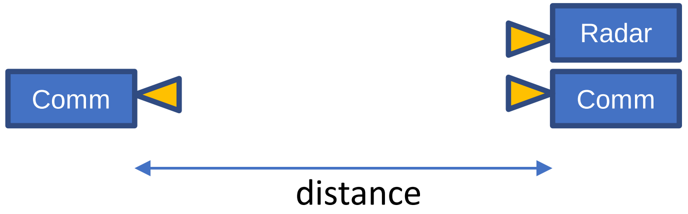
	99% One-Way Latency (msec)	% of over baseline
No Radar	6.88	baseline
Single Burst of 3.3ms	8.70	126%
Soli Burst of 6.4ms	10.43	152%
Continuous radar of 33ms	20.44	297%



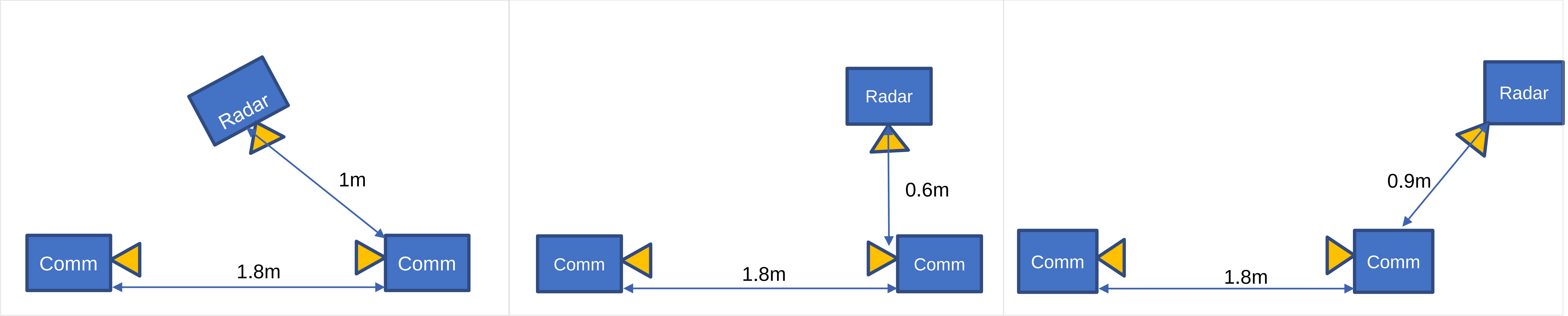
- Observations
  - Soli radar with 6.4ms burst duration is **worse** to 60 GHz communications than the single 3.3ms burst radar, causing one way latency to increase beyond single digit milliseconds
  - Continuous radar pattern that operates continuously in 33ms with very short gaps has the greatest impact to 60 GHz communications. It results in almost 3 times increase in latency.

Assessing Radar Zone of Interference

- Test setup
  - Orientation angles: 0º, 45º,90º,135º
  - Various distances
  - Radar Tx power: 13dBm <u>and</u> 20dBm
  - Radar pattern used: Soli bursts of 6.4ms



0 degrees



45 degrees
90 degrees
135 degrees

Testing Results

Radar EIRP (dBm)	Orientation (deg)	Comm Distance d_c (m)	Radar Distance d_r (m)	99% One-Way Latency (msec)
13	0	3	3	10.12
20	0	3	3	11.02
13	45	1.8	1	9.94
20	45	1.8	1	10.91
13	90	1.8	0.6	8.34
20	90	1.8	0.6	10.55
20	135	1.8	0.9	6.94

- 20dBm radar power significantly increases the zone of interference compared to 13dBm radar power
  - At minimum it doubles the range of the interference zone and widens the impact angle
- At 0^o angle, 13dBm radar causes more than 10 ms latency at 3m range
  - 20dBm radar power will have an even longer (>3m) interference impact range (not tested because of lab constraints)
- At 45^o angle, 20dBm radar causes more than 10 ms latency at 1 m; 13dBm radar barely meet 10ms latency at 1 m
- At 90^o angle, 20dBm radar causes more than 10 ms latency at 0.6 m

Conclusions

- Radar degrades the 60 GHz communication latency performance critical to emerging AR/VR/XR applications
- Radar transmissions with short gaps between chirps and long burst duration greater than 3.3ms increase 60 GHz communications one-way latency well beyond single digit milliseconds
- 20 dBm radar power increases interference zone; impact range at least doubles and impact angle is greatly widened

Our goal is to ensure the 60 GHz band successfully supports *both* communications and radar operations today and well into the future

Thank you

Appendix

IEEE RTA TIG Report

Use cases		Intra-BSS latency (ms)	Jitter variance (ms)	Packet loss	Data rate (Mbps)
Real-time mobile gaming		< 5	< 2	< 0.1%	< 1
Cloud gaming		< 10	< 2	Near-lossless	< 0.1 on Reverse link > 5 on Forward link
Real-time video		< 3-10	< 1-2.5	Near-lossless	100-20,000: forward link 10-100 Kbps: reverse link
Robotics and industrial automation	Equipment control	< 1-10	< 0.2-2	Near-lossless	< 1
	Human safety	< 1-10	< 0.2-2	Near-lossless	< 1
	Haptic technology	< 1-5	< 0.2-2	Lossless	< 1
	Drone control	< 100	< 10	Lossless	< 1 > 100 with video

See https://mentor.ieee.org/802.11/dcn/19/11-19-0065-06-0rta-rta-tig-summary-and-recommendations.pptx

3GPP TS 22.261 v18.5.0 (2)

Table 7.6.1-1 KPI Table for additional high data rate and low latency service

Use Cases	Characteristic parameter (KPI)			Influence quantity		
	Max allowed end-to-end latency	Service bit rate: user-experienced data rate	Reliability	# of UEs	UE Speed	Service Area (note 2)
Cloud/Edge/Split Rendering (note 1)	**5 ms** (i.e. UL+DL between UE and the interface to data network) (note 4)	0,1 to [1] Gbit/s supporting visual content (e.g. VR based or high definition video) with 4K, 8K resolution and up to120 frames per second content.	99,99 % in uplink and 99,9 % in downlink (note 4)	-	Stationary or Pedestrian	Countrywide
Gaming or Interactive Data Exchanging (note 3)	**10ms** (note 4)	0,1 to [1] Gbit/s supporting visual content (e.g. VR based or high definition video) with 4K, 8K resolution and up to120 frames per second content.	99,99 % (note 4)	≤ [10]	Stationary or Pedestrian	20 m x 10 m; in one vehicle (up to 120 km/h) and in one train (up to 500 km/h)
Consumption of VR content via tethered VR headset (note 6)	**[5 to 10] ms** (note 5)	0,1 to [10] Gbit/s (note 5)	[99,99 %]	-	Stationary or Pedestrian	-

NOTE 1: Unless otherwise specified, all communication via wireless link is between UEs and network node (UE to network node and/or network node to UE) rather than direct wireless links (UE to UE).
NOTE 2: Length x width (x height).
NOTE 3: Communication includes direct wireless links (UE to UE).
NOTE 4: Latency and reliability KPIs can vary based on specific use case/architecture, e.g. for cloud/edge/split rendering, and may be represented by a range of values.
NOTE 5: The decoding capability in the VR headset and the encoding/decoding complexity/time of the stream will set the required bit rate and latency over the direct wireless link between the tethered VR headset and its connected UE, bit rate from 100 Mbit/s to [10] Gbit/s and latency from 5 ms to 10 ms.
NOTE 6: The performance requirement is valid for the direct wireless link between the tethered VR headset and its connected UE.

See https://www.3gpp.org/ftp/Specs/archive/22_series/22.261/22261-i50.zip